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(54) Production of olefins.

(57) Saturated paraffin hydrocarbons having 4 or more carbon atoms are converted to olefins having fewer carbon atoms by contacting a mixture of 40 to 95 wt % paraffin hydrocarbons having 4 or more carbon atoms and 5 to 60 wt % olefins having 4 or more carbon atoms with solid zeolite catalyst such as ZSM-5 at conditions effective to form propylene and the separation of light olefins from the reaction mixture.

EP 0 395 345 A1

PRODUCTION OF OLEFINS

Field of the Invention

The present invention relates to the conversion of saturated paraffinic hydrocarbons to olefins having fewer carbon atoms. In particular, the invention provides for contact of a mixture of saturated and
5 unsaturated hydrocarbons comprised of 40% to 95% saturated hydrocarbons with solid zeolitic catalyst such as ZSM-5 at conditions effective to form propylene. In preferred practice, light olefins are separated from the reaction mixture, and unreacted saturated feed and product olefin other than the desired light olefins product are recycled for further reactive contact over the zeolite catalyst.

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Description of the Prior Art

Methods are currently known for the production of commercially important olefins such as propylene from paraffinic feed materials. Such methods include steam cracking, propane dehydrogenation, and
15 various refinery catalytic cracking operations.

Each of these procedures has certain disadvantages. For example, propylene yields from steam cracking are not very high, and are not substantially improved by recycling. Purification of non-propylene products is required which is costly or such products have only fuel value.

Propane dehydrogenation processes are characterized by rapid catalyst coking requiring frequent,
20 costly regenerations. Also, reasonable conversions require sub-atmospheric pressures, and propane is difficult to separate from propylene.

Propylene supplies from catalytic conversions are uncertain. Transportation and purification are significant problems.

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Summary of the Invention

The present invention provides an improved process for the selective production of propylene from C₄
30 and higher saturated paraffin hydrocarbon feed, especially C₅-C₂₀ paraffin. According to the invention, the saturated paraffin feed is combined with 5-60 wt.% of olefins having 4 to 20 carbon atoms and the mixture contacted with a zeolitic catalyst such as ZSM-5, at conditions which favor propylene formation, i.e. high temperature and low conversion per pass, and low hydrocarbon partial pressure. Preferably combined with the saturated feed hydrocarbon is a recycle stream containing unreacted feed as well as C₄ + olefins which
35 are formed during the contact with the zeolitic catalyst and which are not the desired reaction product. Surprisingly, conditions which favor propylene formation from the saturated paraffin hydrocarbons also favor propylene formation from butenes and higher olefins, thus providing enhanced selectivity and yields through practice of the invention. It has been found that the provision of olefins in the feed mixture in the designated amounts results in a very substantial enhancement of saturated hydrocarbon conversion.

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Description of Drawing

45 The attached drawing illustrates in schematic fashion preferred practice of the invention.

Detailed Description of the Invention

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Although it is known to convert paraffins to lower olefin-containing mixtures, as above described, prior procedures have not been entirely satisfactory. Yields via steam cracking are not high. Paraffins can be converted by reaction over acidic zeolites, but once again yields are not high.

In accordance with the invention, saturated hydrocarbon conversion to soluble light olefins can be dramatically improved by incorporating C₄ to C₂₀ olefins in the feed mixture and passing the resulting

mixed feed over a zeolitic catalyst at conditions favoring propylene formation.

Saturated hydrocarbons employed as feed are paraffins having at least four carbon atoms and are preferably C_5 to C_{20} paraffins. It is essential that the feed mixture to the catalyst contain about 40 to 95 wt.% of these paraffins based on the total of paraffins and olefins for the reforming of the present invention to be realized.

Combined with the paraffins in the conversion feed mixture are C_4 to C_{20} olefins in amount of 5 to 60 wt.% based on the total of paraffins and olefins, preferably 10 to 50 wt.% olefins.

The feed mixture may also contain aromatics, naphthenes and inerts such as nitrogen, but the benzene content should not exceed 30 wt.% of the total feed. At benzene concentrations above 40 wt.%, alkylation becomes significant and light olefin yields are reduced. The feed mixture may also contain steam in amount up to 30 mol. %, preferably 1 to 20 mol. %.

The accompanying drawing illustrates a particularly preferred practice of the invention involving recycle of C_4 and higher olefins formed during the paraffin conversion.

Referring to the drawing, the paraffin hydrocarbon feedstock, e.g., C_6 - C_{20} paraffin hydrocarbons, passes via line 1 to reaction zone 2. Recycle comprised of unreacted paraffins and C_4 olefins passes via line 3 and is combined with the net paraffin feed to form a mixture of 40 to 95 wt.% paraffins, and this mixture is fed to zone 2. In zone 2 the mixed hydrocarbon feedstock is contacted with the zeolite solid contact catalyst at reaction conditions which favor production of propylene from both the paraffin and olefin feed materials.

Conditions favoring propylene production involve low hydrocarbon partial pressure, high temperatures and low per pass conversions as described later.

The product mixture from reaction zone 2 passes via line 4 to separation zone 5 wherein the components of the product mixture are separated by conventional means such as fractional distillation.

An overhead mixed ethylene and propylene stream is removed from zone 5 via line 6 and comprises the preferred product mixture. Higher boiling compounds are removed via line 7; a small purge of hydrocarbons suitable as gasoline blending stock is separated as by distillation (not shown) via line 8 with the remainder of the materials boiling higher than propylene being recycled via line 3 for further reaction in zone 2 after being combined with the fresh paraffin feed introduced via line 1.

In order to more clearly describe the invention particularly in comparison to procedures which are not in accordance with the invention, reference is made to the following examples.

Comparative Example A

H ZSM-5, 20 x 40 mesh, in amount of 0.25 grams was admixed with 3.5 grams of similar mesh size alpha alumina and loaded into a 36 inch tubular reactor made from 5/8 inch OD tubing having 0.065 inch wall thickness. Reactor heating was by an electric tube furnace.

Normal octane was fed to the top of the reactor where it was preheated to 510° C before contacting the catalyst. Conditions in the catalyst bed were maintained at about 527° C and 6 psig. Octane feed rate was 250 cc/hr giving a WHSV of about 700 hr⁻¹ based on the ZSM-5. Residence time was about 0.1 second.

The reactor was operated for 1 hour between regenerations. Regeneration consisted of feeding 5% O₂ for 28 minutes and full air for 28 minutes followed by 4 minutes of nitrogen purge.

Octane conversion was 22%, and the wt. % selectivities achieved on a hydrogen-free and coke-free basis were:

Methane	0.4
Ethylene	4.59
Ethane	2.55
Propylene	27.88
Propane	14.90
Butenes	21.89
Butanes	16.14
Pentenenes	9.77
Pentanenes	6.36
C ₆ 's	3.46
C ₇ 's	2.93
C ₈	6.94

Example 1

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Comparative Example A was repeated except that, pursuant to the instant invention, an equal volume of the C₄ reaction products (containing unreacted octane and olefins) was continuously recycled to the reaction and combined with the fresh octane feed. The combined feed contained 2.4 wt.% propylene and 7.2 wt.% C₄ plus C₅ olefins. The n-octane concentration in the combined feed was 85 wt.%. Residence time was 0.05 second. The WHSV including the recycle was about 1400 hr⁻¹.

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Overall octane conversion was 31% and overall wt.% selectivities on a hydrogen-free and coke-free basis were:

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Methane	0.59
Ethylene	6.32
Ethane	2.55
Propylene	27.88
Propane	14.90
Butenes	21.34
Butanes	6.86
Pentenenes	5.66
Pentanenes	4.70
C ₆ 's	2.28
C ₇ 's	2.06
C ₈	3.96

It will be seen from a comparison of Example 1 and Comparative Example A that practice of the invention dramatically improved overall octane conversion as well as overall propylene selectivity. The butane and pentane selectivities were sharply reduced.

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Comparative Example B

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Comparative Example A was repeated except that the feed was cis/trans butene-2 rather than n-octane. Butene conversion was 65% and the wt.% selectivities on a hydrogen-free and coke-free basis were:

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Methane	0.05
Ethylene	4.20
Ethane	0.10
Propylene	20.50
Propane	3.20
Butanes	6.56
C ₅ +	56.26

This Comparative Example B demonstrates about the same selectivity to propylene as Example 1 and illustrates that surprisingly both saturated hydrocarbons and olefins are converted to propylene with good efficiency at the same reaction conditions.

Comparative Example C

A full range naphtha (C₅ to C₁₂), condensed from an Algerian natural gas well, was fed to a steam cracker at an 0.75 steam to oil ratio. The weight % yields are shown below at the indicated coil temperatures:

Coil Outlet Temp, °C	815	849
Yields, wt %		
Hydrogen	0.8	1.0
Methane	12.8	16.5
Acetylene	0.3	0.6
Ethylene	25.0	30.0
Ethane	3.7	3.4
Methylacetylene/Propadiene	0.6	0.7
Propylene	16.9	12.1
Propane	0.7	0.5
Butenes	5.7	3.2
Butanes	1.1	0.4
Butadiene	4.6	3.9
C ₅ 's	5.4	3.2
Benzene	6.6	9.1
Toluene	3.7	4.1
C ₈ Aromatics	2.5	2.7
C ₆ to C ₈ Non-aromatics	4.1	1.0
C ₉ +	5.5	7.5

Comparative Example D

0.15 grams of ZSM-5 catalyst, 100 x 140 mesh was mixed with 4.5 grams of Alcoa T-64 alpha alumina and loaded into the reactor of Example A. The reactor was heated with an electric tube furnace. Temperatures in the catalyst bed were measured with an axial thermowell. Algerian condensate as in Example C was pumped into the top of the reactor at the rate of 60 cc/hr. The catalyst bed was maintained at 621 °C and 0.5 psig. The gas and liquid reaction products were analyzed and the results are shown below:

Overall conversion, %	54
Yield, Vol%	
Methane	3.1
Ethylene	9.5
Ethane	3.5
Propylene	18.3
Propane	2.3
Butenes	8.2
Butane	4.3
Butadiene	0.2
C ₅ olefins	2.5
C ₅ paraffins	1.1
C ₆ + aromatics	3.3
C ₆ + paraffins (unreacted feed)	42.7

Example 2

The process of the present invention was carried out using the Algerian condensate also used in Comparative Examples C and D. Conditions of the reaction were the same as those in Comparative Example D. In carrying out the process, effluent from the reactor was distilled to separate a C₃ and lighter product stream from a C₄ and heavier stream which was recycled. The volume ratio of fresh feed to recycle was varied. The results achieved are as follows:

Recycle Ratio				
Recycle/Fresh Feed	1.0	2.0	4.0	
Overall Yields, wt % (based on fresh feed)				
Methane	6.1	6.7	7.0	
Ethylene	16.3	18.2	19.2	
Ethane	5.6	6.1	6.4	
Propylene	32.9	37.5	40.1	
Propane	3.9	4.3	4.6	
Butanes	7.3	8.2	8.8	
Butenes	4.6	2.5	1.2	
C ₅ +	23.3	16.5	12.7	

As shown in Comparative Example C, steam cracking is capable of a 17% propylene yield and this will not increase beyond 20% with recycle because the once through C₄ + steam cracking products are not well suited for making propylene. Through practice of the present invention, propylene yields as high as 40% can be achieved thus demonstrating the surprising superiority of the invention.

Comparative Example E

10.0 grams of Intercat Zcat-plus, 40X60 mesh, was loaded into a 3/4" ID Alumina tube. The catalyst bed was supported with a 1/2" OD alumina tube from the bottom. A layer of Denstone 57 inert spheres was placed on top. The ceramic tube was placed inside a 1.8" OD stainless steel shield. The entire assembly was mounted in an electric tube furnace. 93 gm/hr of n-butane and 6 gm/hr of distilled water were fed to the catalyst bed, which was maintained at about 593° C and 1 psig. After 30 minutes the butane feed was

stopped and the catalyst bed was regenerated using air, steam and nitrogen. The regeneration was conducted for 30 minutes also. Following this, the reaction was again started and the catalyst bed was brought to steady state was reached. When steady state was reached, the following data were obtained:

Conversion of N-butane, %	7.2	10.9
Selectivity, wt %		
Methane	14.05	15.90
Ethylene	15.66	19.14
Ethane	12.51	10.23
Propylene	38.35	40.72
Propane	1.21	1.62
Butanes	16.12	9.54
Isobutane	0.80	0.24
Pentenes	0.0	0.93
Pentanes	0.0	0.0
C ₆	0.25	0.79

Comparative Example F

The procedure of Example E above was repeated, except the temperature was raised to 635° C and the feed was changed to isobutane.

Conversion of Isobutane, %	16.1
Selectivity, wt %	
Methane	12.6
Ethylene	3.7
Ethane	0.26
Propylene	34.13
Propane	1.95
n-butane	1.38
Butenes	39.21
C ₅	6.77

Example 3

Using the same procedure as Example E, gasoline hydrocarbon mixture was fed to the catalyst bed at a rate of 108 grams per hour. The temperature and pressure in the catalyst bed were maintained at 593° C and 2 psig, respectively. The feed, analyzed by FIA and GC had the following composition:

Olefins	10.5 vol%	Isobutane	3.6 Wt%
Saturates	61.0%	N-butane	5.6%
Aromatics	28.5%	Pentanes	15.3%

At steady state, the overall conversion was 20.3%. The component selectivities and conversions are

presented below:

	Selectivity, wt. %	Component Conversion
H ₂ + Coke	1.44	
Methane	3.68	
Ethylene	16.20	
Ethane	2.97	
Propylene	42.02	
Propane	2.67	
Isobutane		32.3
BD	0.24	
N-butane		21.9
Butenes	12.32	
Putenes		62.4
Pentanes		19.4
C ₆ 's		33.2
Benzene	5.44	
C ₇ 's		36.7
Toluene	7.23	
C ₈ Non-Aromatics		21.7
C ₈ Aromatics	4.28	
C ₉	1.52	

Comparing Example 3 with Examples E and F indicates that the conversions of N-butane and isobutane are doubled in the presence of olefins.

Example 4

A C₄-C₆ cut was taken from an FCC unit and reacted using the same procedure as Example E. The olefin concentration in this stream was 55 wt%. The balance was paraffins, including 17.1 wt% isobutane and 7.6 wt% n-butane. 100 gm/hr of this mixture was fed to the catalyst bed, which was held at 593 °C and 1 psig. The results are summarized below:
Overall Conversion: 34%

	Selectivity, wt %	Component Conversion, %
Methane	1.51	
Ethylene	16.04	
Ethane	0.60	
Propylene	53.22	
Propane	2.10	
Isobutane		25.5
BD		59.3
N-butane		3.2
Butenes		46.0
Pentenenes		59.2
Pentanes	14.36	
C ₆ 's		35.0
benzene	1.84	
C ₇ 's	2.86	
Toluene	4.10	
C ₈ ⁺	3.18	

The isobutane conversion here is nearly double that of Example E, in spite of the lower temperature and lower isobutane concentration. This suggests olefins in the feed are increasing the rate of paraffin consumption.

Comparative Example G

BT Raffinate, containing the components listed below, was reacted according to the procedure of Example E at feed rate of 210 gm/hr:

	Feed, wt%
Butenes	0.19
Pentenenes	0.21
Pentanes	5.91
Hexanes	65.88
Benzene	1.51
Heptanes	19.20
Toluene	2.10
C ₈ ⁺	3.00

The total olefin content of this stream is 0.4 wt%. The catalyst bed was maintained at 538° C and 9 psig. The results are shown below:

	Selectivity, wt %	Component Conversion, %
Coke + H ₂	1.25	
Methane	2.82	
Ethylene	7.84	
Ethane	3.35	
Propylene	38.05	
Propane	4.45	
Butenes	28.65	
Butanes	1.40	
Pentenes	7.80	
Pentanes		2.99
Hexanes		15.04
Benzene	1.53	
Hexanes		18.73
Toluene		1.71
C ₈	2.87	

The relative conversions of C₅, C₆ and C₇ paraffins are not surprising, since reactivity increases with molecular weight.

Example 5

According to the invention, a C₄-C₆ cut containing 55 wt% olefins was taken from an FCC unit and fed according to the procedure of Example E at the rate of 195 gm/hr. The composition of the stream is presented below:

	Feed, wt%
Propylene	0.10
Propane	0.14
Isobutane	17.11
N-butane	7.60
Butenes	39.23
Pentenes	16.36
Pentanes	13.80
C ₆	5.66

The catalyst bed was maintained at 538° C and 9 psig. The C₃ and lighter portion of the reactor effluent was separated by continuous fractionation and removed as product. The C₄ portion of the effluent was recycled back to the reactor inlet at a rate of 256 gm/hr and mixed with the fresh feed prior to contact with the catalyst bed, bringing the total feed rate to 451 gm/hr. The composition of the combined feed is shown below:

	Feed, wt%
Propylene	1.61
Propane	0.06
Isobutane	13.25
N-butane	7.59
Butenes	26.39
Pentenenes	21.49
Pentanenes	15.27
C ₆	14.34

The total concentration of olefins in the reactor feed was 49.5 wt%.

The overall conversion of the fresh feed was 32%. The overall selectivities and component conversions are shown below:

	Overall Selectivity, wt%	Overall Conversion %
Methane	0.26	
Ethylene	11.05	
Ethane	0.23	
Propylene	75.09	
Propane	1.83	
Isobutane		6.35
N-butane		3.65
Butenes		56.03
Pentenenes		26.53
Pentanenes		29.56
C ₆	11.43	

Comparing Example G with Example 5 shows the increase in C5 paraffin conversion resulting from the presence of olefins in the feed. It is surprising that the C₅ paraffin conversion in Example 5 is ten times higher than Example G, in spite of the fact that the space velocity is twice as high. This result shows the beneficial effect of olefins on the conversion of paraffins.

Example H

The procedure of Example E was repeated, except the feed was isobutane, the temperature was raised to 635° C and the pressure was raised to 12 psig.

Conversion of Isobutane, %	23.7
Selectivity, wt%	
Methane	12.47
Ethylene	8.03
Ethane	0.62
Propylene	35.83
Propane	4.26
N-butane	1.77
Butenes	29.02
C ₅	5.96

Example 6

Example 4 was repeated, except at 12 psig pressure. The overall conversion was 42.3%

	Selectivity, wt %	Component Conversion, %
Methane	7.9	
Ethylene	18.8	
Ethane	2.6	
Propylene	51.4	
Propane	4.6	
Isobutane		33.1
BD		57.8
N-butane	13.5	
Butenes		61.8
Pentenes		65.7
Pentanes	2.8	
C ₆	11.4	

A comparison of Example 6 with example H shows that the isobutane conversion in Example 6 is measurably higher even though the temperature was 24° C lower. This is due to the olefins present in the feed to Example 6.

Saturated paraffin hydrocarbons used as feed in accordance with the invention are those having 4 or more carbon atoms, especially C₅-C₂₀. Individual hydrocarbons or mixtures can be employed. Preferred hydrocarbons are those having from about 6 to 20 carbons, especially petroleum fractions for reasons of costs. Specific hydrocarbons include hexane, the methyl pentanes, cetane, etc.

The conversion is carried out at elevated temperatures in the range of about 400 to 800° C, preferably 500 to 700° C.

Low hydrocarbon partial pressures and low conversions per pass favor propylene production. The feed hydrocarbon can be admixed with steam or inert gas such as nitrogen. The hydrocarbon partial pressure is as low as practical, illustratively 1 to 30 psia. Where no diluents are employed, system pressures ranging from about -12 to 50 psig, preferably -5 to 30 psig are suitable. Higher pressures can be used when diluents are employed.

High space velocity and short residence times are preferred in order to maintain the desired low conversions per pass. Paraffin hydrocarbon conversions per pass are less than 50%. Space velocities depend on the particular zeolite used and are 1 to 5000 preferably 5 to 200° hr⁻¹ WHSV. Reactor residence times are 0.001 to 20 seconds, preferably 0.01 to 5 seconds.

The conversion reaction of the instant invention is highly endothermic. Preferably fluidized solid catalyst conversion procedures are used with the feed hydrocarbon vapor contacting fluidized particles of the zeolite

catalyst. Heat necessary to maintain the reaction is provided by separately heating the catalyst particles in a fluidized regeneration zone as by combustion of appropriate fuel hydrocarbon.

Fixed bed procedures can be employed. In such cases, the use of reaction zones in series with interstage heating is advantageous.

5 Zeolite catalysts used in the invention can be siliceous, crystalline molecular sieves. Such silica-containing crystalline materials include materials which contain, in addition to silica, significant amounts of alumina. These crystalline materials are frequently named "zeolites, i.e., crystalline aluminosilicates. Silica-containing crystalline materials also include essentially aluminum-free silicates. These crystalline materials are exemplified by crystalline silica polymorphs (e.g., silicalite, disclosed in U.S. Pat. No. 4,061,724 and
10 organosilicates, disclosed in U.S. Pat. No. Re. 29948), chromia silicates (e.g., CZM), ferrosilicates and galliosilicates (see U.S. Pat. No. 4,238,318), and borosilicates (see U.S. Pat. Nos. 4,226,420; 4,269,813; and 4,327,236).

Crystalline aluminosilicate zeolites are best exemplified by ZSM-5 (see U.S. Pat. Nos. 3,702,886 and 3,770,614), ZSM-11 (see U.S. Pat. No. 3,709,979), ZSM-12 (see U.S. Pat. No. 3,832,449), ZSM-21 and
15 ZSM-38 (see U.S. Pat. No. 3,948,758), ZSM-23 (see U.S. Pat. No. 4,076,842), and ZSM-35 (see U.S. Pat. No. 4,016,246).

Phosphorous containing zeolites are suitably used (see U.S. Patent 3,972,832) and in such cases it is especially advantageous to add steam to the feed mixture.

Acid zeolites are especially preferred, particularly the ZSM type and borosilicates. ZSM-5 is especially
20 useful.

In addition to the above, zeolite containing materials can be used. Representative of such materials are zeolite A (U.S. Patent 2,882,243), zeolite X (U.S. Patent 2,882,244), zeolite Y (U.S. Patent 3,130,007), zeolite ZK-5 (U.S. Patent 3,247,195), zeolite ZK-4 (U.S. Patent 3,314,752), synthetic mordenite, and dealuminized mordenite, as well as naturally occurring zeolites, including chabazite, faujasite, mordenite, and the like.

25 In general, the zeolites are ordinarily ion exchanged with a desired cation to replace alkali metal present in the zeolite as found naturally or as synthetically prepared. The exchange treatment is such as to reduce the alkali metal content of the final catalyst to less than about 1.5 weight percent, and preferably less than about 0.5 weight percent. Preferred exchanging cations are hydrogen, ammonium, rare earth metals and mixtures thereof, with particular preference being accorded rare earth metals. Ion exchange is suitably
30 accomplished by conventional contact of the zeolite with a suitable salt solution of the desired cation, such as, for example, the sulfate, chloride or nitrate salts.

It is preferred to have the crystalline zeolite of a suitable matrix, since the catalyst form is generally characterized by a high resistance to attrition, high activity and exceptional steam stability. Such catalysts are readily prepared by dispersing the crystalline zeolite in a suitable siliceous sol and gelling the sol by
35 various means. The inorganic oxide which serves as the matrix in which the above crystalline zeolite is distributed includes silica gel or a cogel of silica and a suitable metal oxide. Representative cogels include silica-alumina, silica-magnesia, silica-zirconia, silica-thoria, silica-beryllia, silica-titania, as well as ternary combinations, such as silica-alumina-magnesia, silica-alumina-zirconia and silica-magnesia-zirconia. Preferred cogels include silica-alumina, silica-zirconia or silica-alumina-zirconia. The above gels and cogels will
40 generally comprise a major proportion of silica and a minor proportion of the other aforementioned oxide or oxides. Thus, the silica content of the siliceous gel or cogel matrix will generally fall within the range of 55 to 100 weight percent, preferably 60 to 95 weight percent, and the other metal oxide or oxides content will generally be within the range of 0 to 45 weight percent, and preferably 5 to 40 weight percent. In addition to the above, the matrix may also comprise natural or synthetic clays, such as kaolin type clays, montmorillonite, bentonite or halloysite. These clays may be used either alone or in combination with silica or any of
45 the above specified cogels in a matrix formulation.

Claims

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1. The method of preparing olefins from paraffin hydrocarbon feedstock which comprises:

(a) feeding a mixture of 40 to 90 wt % paraffin hydrocarbon having 4 or more carbon atoms and 5 to
60 wt % olefin having 4 or more carbon atoms to a reaction zone containing a zeolite catalyst,

(b) contacting said mixture with said catalyst at reaction conditions favoring conversion of said mixed
55 stream to propylene, and

(c) separating product C₂-C₃ olefins from the reaction mixture.

2. The method of claim 1 wherein the paraffin hydrocarbon feedstock is a C₅ to C₂₀ paraffin hydrocarbon or hydrocarbon mixture.

EP 0 395 345 A1

3. The method of claim 1 or claim 2 wherein the reaction conditions of step (b) include a reaction temperature in the range 400 to 800 °C.

4. The method of any one of claims 1 to 3 wherein the hydrocarbon partial pressure in step (b) is 1 to 30 psia.

5. The method of any one of claims 1 to 4 wherein the zeolite catalyst is ZSM-5.

6. A method as claimed in any one of claims 1 to 5 including the further step of recycling to step (a) olefins formed in step (b) and having 4 or more carbon atoms and unreacted paraffin hydrocarbon.

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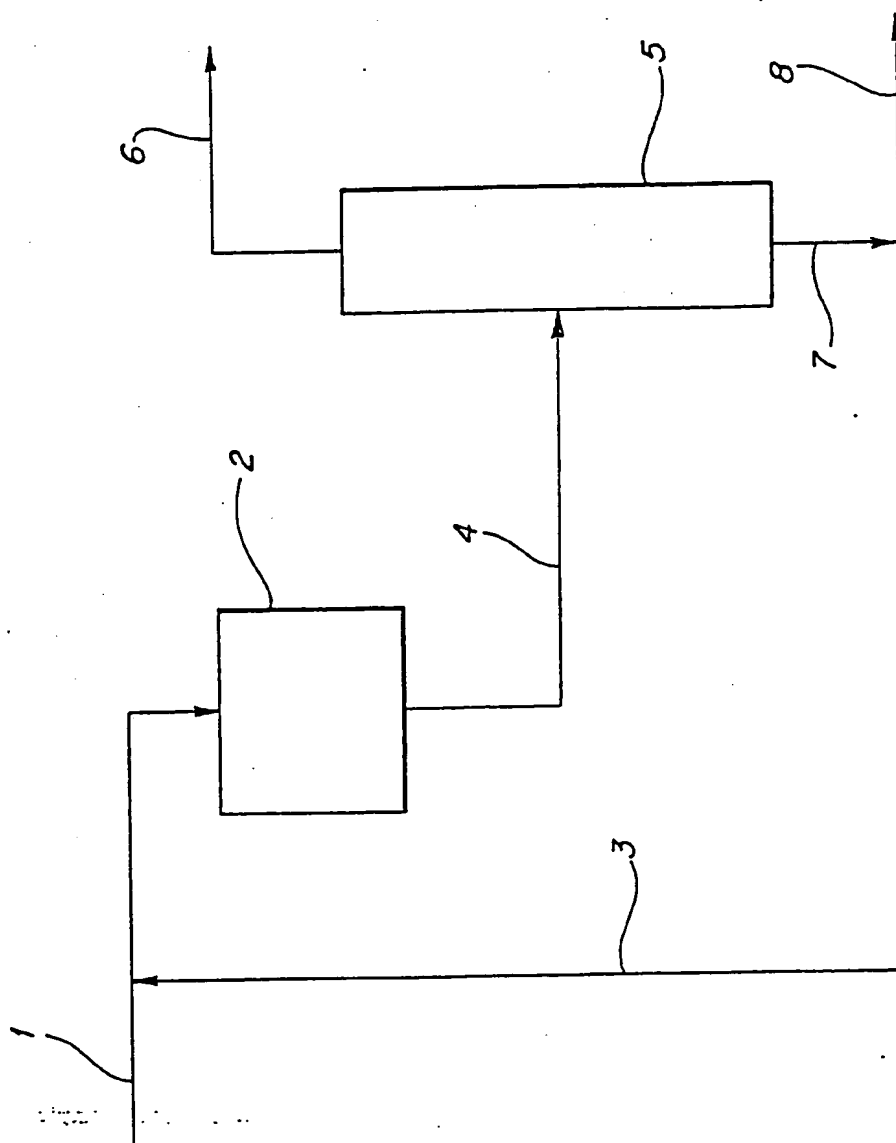
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European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 30 4364

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	EP-A-0 288 363 (IFP) * Claims 1,10; page 8, lines 1-19; example 8 *	1,3	C 10 G 11/05
A	US-A-4 282 085 (O'REAR et al.) * Claims 1,2,9; column 3, line 55 - column 4, line 3 *	1,3,4,5	
A	FR-A-2 373 601 (INSTITUTUL DE INGINERIE TECHNOLOGICA PROIECTARE PENTRU INDUSTRIA CHIMICA) * Claim; page 4, lines 1-16; tables 4,5; examples 2,4 *	1,2,3	
A	US-A-3 926 781 (GALE)		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			C 10 G
The present search report has been drawn up for all claims			
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